





The herringbone pattern occurs because people cut trees along roads.

Opposite: Landsat's 40-year record helps countries track deforestation over time. This image pair shows the Amazon rainforest Brazil's Rondonia state in 1989 (left) and 2008 (right).



FORESTS

Counting the World's Trees | Holli Riebeek

How many trees are there in the world? It's more than a trivia question, and one that the United Nations Food and Agriculture Organization (FAO) has been striving to answer every 5 to 10 years since 1946.

When the United Nations first began its global surveys of the world's forests, it wanted to know how much timber remained. Decades later, the surveys—called the Global Forest Resources Assessments (FRA)—serve a far wider purpose.

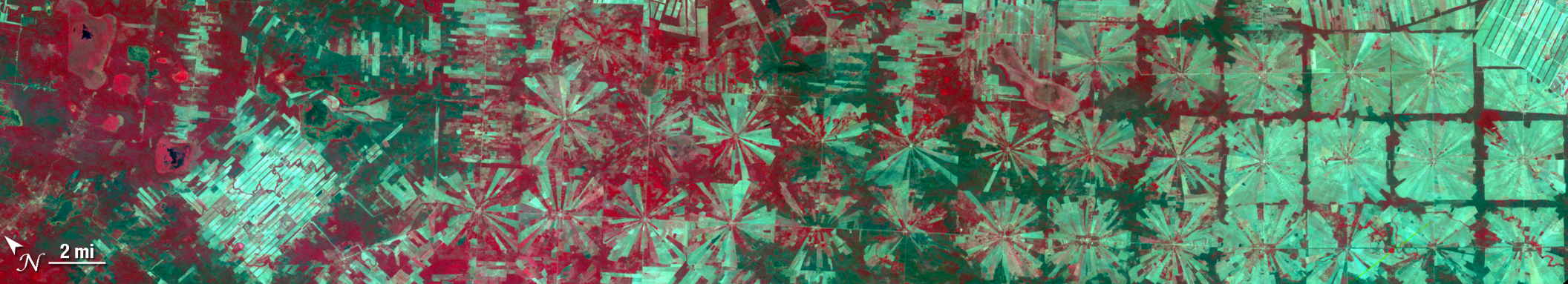
“The basic fact is that natural resources, like forests and land to grow crops, are getting more and more scarce,” says Alan Belward in an interview with EarthSky. Belward heads the Land Resource Management Unit of the European Commission's Joint Research Center (JRC) in Ispra, Italy, where he worked on the latest UN global forest remote sensing survey in 2010—the most comprehensive survey to date.

“There are all sorts of competing demands on our resources,” continues Belward. “Do you use a forest as a carbon sink? Do you use it as a protected area for biodiversity? Or do you use it for fuel wood? To make sensible decisions on trade-offs between different uses, you need evidence on where these resources are, what sort of condition they're in, and how they're changing.” ▶



[Photo Information](#)

Opposite: Oregon's old growth coastal forest is an important wildlife habitat. Credit: David Patte/U.S. Fish and Wildlife Service. Below: Forests are a source of clean water. Credit: David Patte/U.S. Fish and Wildlife Service. Above: Recreation is one of many uses for forest landscapes.



[Image information](#)

Landsat satellites have been in orbit since 1972, providing a long record of deforestation patterns. This image shows an unusual star-shaped pattern in Bolivia. The image was made from near infrared, red, and green light. Forest is dark red, while bare to lightly vegetated ground ranges from tan to green.

Landsat, a Consistent Ruler

The global surveys provide decision makers with a regular, consistent assessment of the extent of the world's forests and how they are changing. The surveys have traditionally been a compilation of reports from individual countries. Norway and Nigeria each survey their forests, for example, and report forested area to the UN Food and Agriculture Organization. However, the two countries may use different survey methods, and so the measurements between countries aren't necessarily comparable.

More recently, thanks to Belward and his colleagues, the surveys have incorporated Landsat satellite measurements of forest extent as a consistent "ruler" for all countries. "We've taken about 13,000 plots around the world which are distributed uniformly, every 60 miles or so, north, south, east, and west. We take a sample plot and we map the change in an area of about 25 acres. That is done 13,000 times in 1990, in 2000, and in 2005," says Belward. This global remote sensing survey is a complement to the compilation of national reports carried out under the Forest Resource Assessment of 2010.

Previous efforts carried out in 1990s used between 100 (TREES-II survey) and 120 (FAO FRA-2000) Landsat images,

says Frédéric Achard also of the European Commission's Joint Research Center. The Food and Agriculture Organization and the Joint Research Center were able to use 13,000 images at three dates over 190 countries in the most recent survey because Landsat data are now available from the United States Geological Survey free of charge. "In the 1990s the cost of one Landsat TM image was about \$2,500. The cost went down to about \$600 in the mid 2000s before being released free of charge starting in December 2008. The cost of the imagery was prohibitive to cover extensive areas" says Achard.

The change from 100 images to 13,000 is significant because the view from Landsat is ideal for forest monitoring. Each pixel in a Landsat image measures 30 meters by 30 meters—about the size of a baseball diamond. "To see fine-scale deforestation, we need Landsat," says Achard. "A coarser resolution satellite doesn't allow providing accurate estimates of deforestation on its own."

Seeing Forest Health

The images are far more than photos, says Belward. Landsat records reflected light in both visible wavelengths and infrared wavelengths invisible to the human eye. By measuring the strength of reflect light in multiple wavelengths, research-

ers can get a sense of not just where the forests are, but how healthy they are.

"We're able to pick up subtle changes in the forest canopy. You can see where you've got largely undisturbed forests or where a logging road has gone in or where it's been clear felled to convert it to other lands," says Belward.

Computer algorithms help researchers sort through hundreds of thousands of scenes and classify forested versus non-forested ground. "The computers work well where the Landsat images have a high spectral contrast between forested and non-forested land like in the Amazon basin during short dry season," says Achard. Low contrast areas like the dry forests and shrublands of Africa pose a challenge. In these cases, regional experts also examine the images and provide visual corroboration to correct the computer outputs.

Global Deforestation

Achard, Belward and others also use Landsat data to determine how forests are changing. Landsat satellites provide a 40-year record, which means that measurements taken in 1985 can be compared to measurements taken in 2012. This allows researchers to map change over time, offering a startling picture of how quickly the world's forests are disappearing. ►

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Protecting the biodiversity of forests sometimes conflicts with other demands on forest resources such as timber. Making national and international decisions on forest management requires knowing where forests are, what conditions they're in, and how they're changing. Researchers are conducting large-scale surveys of forests of around the globe with the help of Landsat. Credit: terex (left) and Taina Sohlman (right), both Fotolia.com.

“About 30 percent of the whole planet’s land area, starting in 2005, was covered in forest. And rather worryingly between 1990 and 2005, we’ve lost about 180 million acres of forest,” says Belward. “We’re losing about a football field worth of forest every four seconds of every minute of every day. That’s net loss. That’s including all the new trees that have been planted around the world.”

Reducing Deforestation

The ability to see deforestation over the past forty years is increasingly important.

Not only does the historical view provide context for future decisions, it may become the basis for international policy. Under an emerging mechanism of the United Nations Framework Convention on Climate Change (UNFCCC) called Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (REDD+), donor countries agree to provide incentives to developing countries to reduce their deforestation and degradation rates and to leave their forest intact in order to reduce global carbon emissions and mitigate future climate change.

The 2010 Global Forest Resources Assessment revealed that deforestation was releasing nearly a billion tons of carbon into the atmosphere per year ($0.9 \pm 0.7 \text{ Pg C}$), a decrease from the previous decade. The UNFCCC REDD item aims to continue the downward trend. Developing countries will voluntarily set carbon emission reference levels based on past rates of deforestation.

To set accurate reference levels which will be used to account for emissions reduction rates, countries need to figure ►



Photo Information
Above: The need for wood products helps drive deforestation.

Listen to Alan Belward talk about the pressures on the world’s forest at http://landsat.gsfc.nasa.gov/news/news-archive/soc_0033.html





Photo Information

Above: Forests such as this at Victoria Falls serve as storage areas for carbon. A program called, “Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (REDD+)” provides incentives to countries to leave their forests intact and thus to reduce global carbon emissions. Landsat provides an objective, reliable source of landscape scale data on how forests are changing over time, and so serves as an important foundation for REDD.

out historical deforestation and emissions. The base year 1990 is used for the Kyoto Protocol, but the base period for REDD+ is not fixed and will depend on individual country capacities and conditions, says Achard. “Wall to wall coverage of the Tropics with Landsat has existed since the 1990s, so we can get historical deforestation estimates for the last 20 years to feed negotiations and allow producing reference levels.” These historical estimates must be as accurate as possible if

Papua New Guinea

1990



2001



Landsat images show change from 1990 to 2001 in a once-forested area near the southeastern tip of mainland Papua New Guinea. Researchers using Landsat and other data sources found evidence of rapid deforestation and degradation, driven primarily by logging, subsistence agriculture, fires, and the development of mines and plantations. “To see fine-scale deforestation, we need Landsat,” says Achard. “A coarser resolution satellite doesn’t provide accurate estimates of deforestation on its own.” Credit: NASA’s Earth Observatory

the program is to work as a market force.

“Countries that have high historical deforestation rates like Brazil and Indonesia have the potential for large payoff by reducing these rates” says Achard. But countries with smaller emissions can also expect incentives through conservation and enhancement of forest carbon stocks. All countries will be rewarded in providing accurate estimates of both historical and current emissions by getting larger pay-

ments. Landsat provides consistent, unbiased estimates of forest cover and deforestation for all countries. The Landsat Data Continuity Mission, to be called Landsat 8 after launch, ensures that observations will be available into the future (from 2013).

Ongoing observations are necessary because the UNFCCC REDD+ mechanism requires annual reports that include the number of hectares of forest lost and the amount of carbon emitted as a result. ▶

FIGURE 5
Annual change in forest area by country, 2005–2010

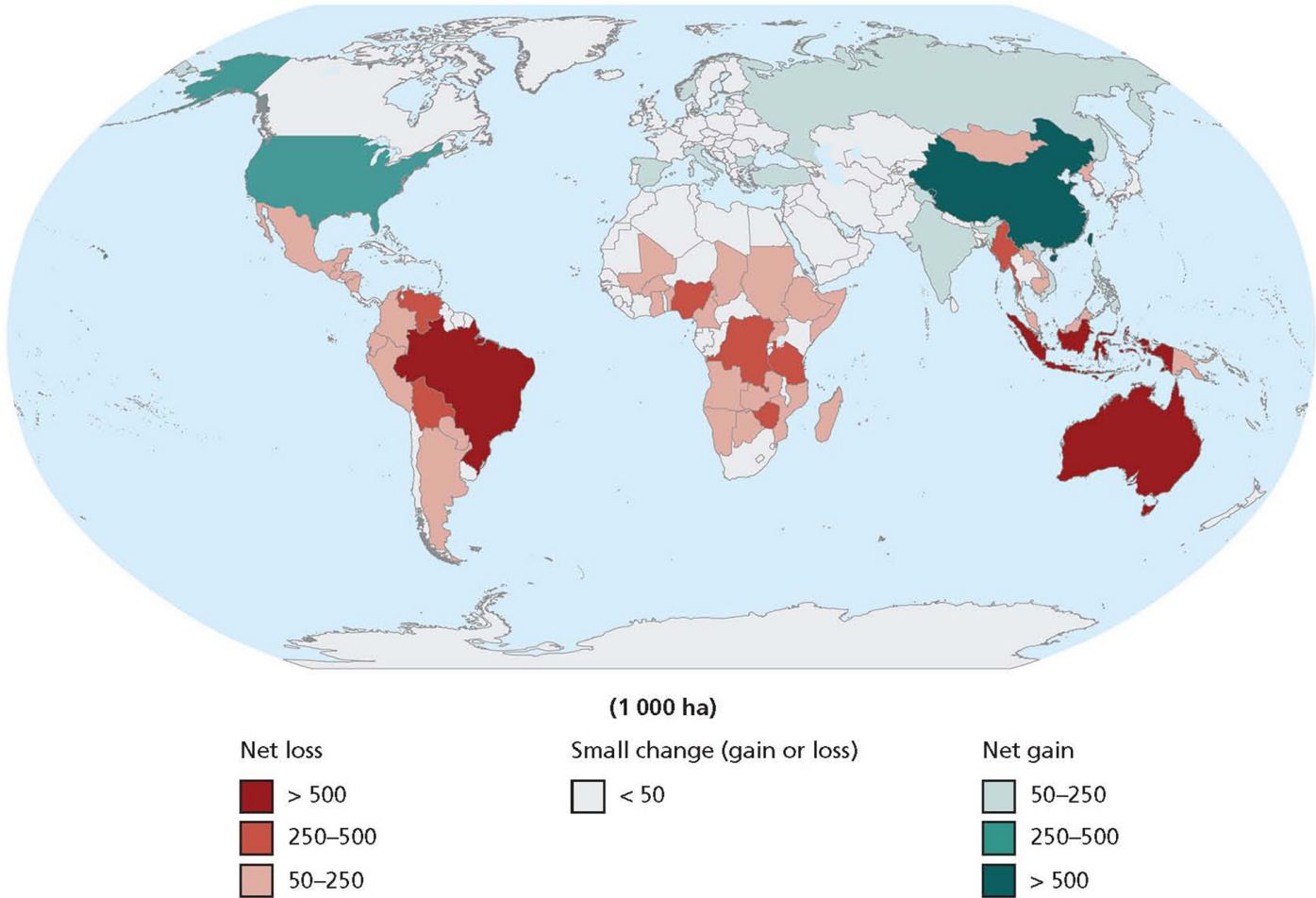
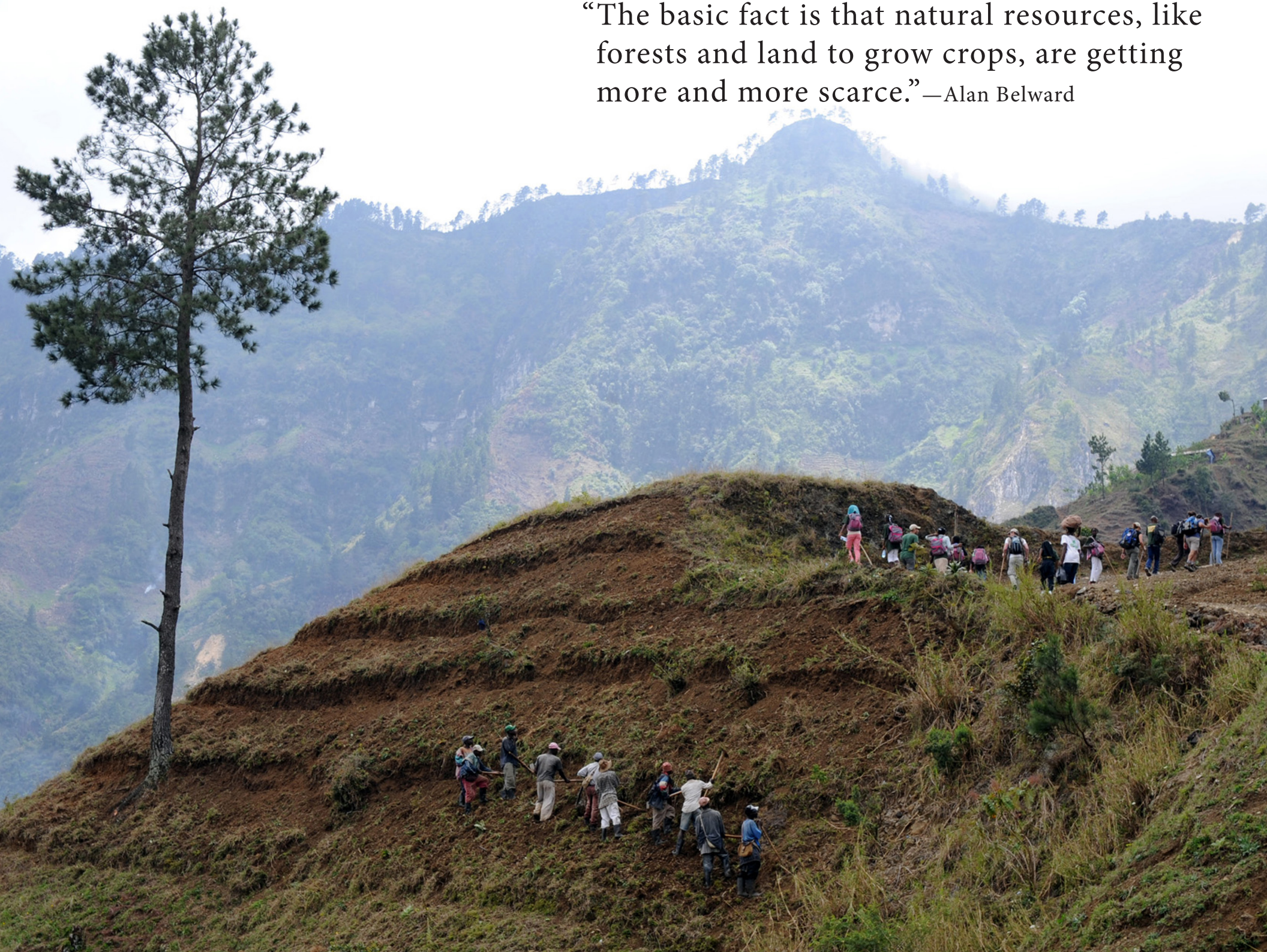


Photo Information:
Not all forest clearing occurs in tropical regions. Landsat 5 acquired this image showing harvest around Mt St Helens in 2011. Tan squares are clear-cut areas. Young forest planted after a clear cut is pale green, while mature forest is dark green. Following full-page photo: Finding land to raise food for the world's growing population places pressure on forests. Decades of deforestation and overfarming have stripped the hillsides of Haiti, leaving less than two percent of the country forested. Credit Kendra Helmer, USAID/Haiti.



Landsat data helped analysts determine how much forest was lost throughout the world between 2005 and 2010. Map courtesy United Nation's Food and Agriculture Organization's 2010 Global Forest Resource Assessment.

“The basic fact is that natural resources, like forests and land to grow crops, are getting more and more scarce.” —Alan Belward



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“Estimates have to be as accurate as possible,” says Achard. “Donors will probably pay only for real reductions in emissions.”

REDD+ is still in an early pilot phase with a handful of countries. It is uncertain how REDD+ will be implemented on a larger scale in an operational phase. The challenge is that many developing countries lack resources to produce regular accurate annual reporting. Landsat-based estimates of deforestation such as those used in the UN FAO Global Forest Resources Assessments are less expensive than an extensive ground-based survey and may turn out to be essential for the success of any deforestation reduction program.

Defining Forest Policy

Regardless of how programs like REDD+ develop, Landsat will continue inform policy through the UN Global Forest Resources Assessment. During Landsat 8's lifetime in orbit, the world's population will likely grow, increasing conflicting demands for food and forest products.

“Our policy makers have an increasing demand for science-based evidence to support their work,” says Belward. “One of our jobs is to provide that evidence.” ■

Meet Frédéric Achard, Scientific Project Leader for the Joint Research Center



Frédéric Achard
Scientific project leader
Joint Research Center
European Commission
Ispra, Italy

“I like to be in the mountains hiking, alpine skiing, or rock climbing,” says Frédéric Achard of Nice, France. When it came time to choose a career field for his university education, Achard wanted to do something to preserve the resources that propelled him to spend his time outdoors. “I knew I wanted to work in the forestry

field, managing public forests for the National Forest Office in France.”

After two years of studying math and science, he entered the Ecole Polytechnique in Palaiseau (20 km south of Paris) followed by National School for Rural Engineering, Water and Forests in Paris, where he obtained the equivalent of a master's degree in forestry. Opportunity led him a different direction than he planned. The school offered a PhD program in remote sensing, for which he was hosted by an Institute specialized in tropical vegetation mapping at University of Toulouse. “There were good opportunities for research in remote sensing applied to tropical forest assessment,” says Achard.

Rather than manage France's forests, Achard decided to apply his expertise to monitoring the world's forests. He is now a scientific project leader with the European Commission's Joint Research Center where he works on TREES-3, a project that uses Landsat data to map forest cover changes throughout the Tropics and Eurasia. “The research is challenging. It's not routine. I have a lot of freedom to explore innovative new ideas.”

Satellite Data Requirements:



16-day revisit



5-30 m resolution



Vis, NIR, SWIR



Global coverage



Archive continuity & consistency



Free, unrestricted data



geolocation ≥ 15 m



$\leq 5\%$ radiance calibration

See inside back cover for more information